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The Correlation Between Lighting Intensity, Eye Fatigue, Occupational Stress, and Sleep Quality in the Control Room Operators of Abadan Refinery

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Abstract

Background: The control room is a critical work environment where optimal performance is essential to minimize errors. Lighting is one of the key environmental factors influencing the performance of control room operators. Inadequate sleep quality and job stress also significantly impact job performance. Poor sleep quality, eye fatigue, inappropriate lighting, and occupational stress can lead to errors and decreased accuracy in work.

Objectives: The present study aims to determine the correlation between lighting intensity, eye fatigue, occupational stress, and sleep quality among control room operators at the Abadan Refinery. The study was conducted in 2022.

Methods: This cross-sectional descriptive-analytical study was conducted on 190 control room operators at the Abadan Refinery in 2022. A lux meter device was used to evaluate the intensity of lighting. Standard Pittsburgh sleep quality, eye fatigue, and Occupational Stress questionnaires were also administered. The results were analyzed using SPSS software.

Results: The average light intensity of the work surface was 347.95 ± 147.34 lux. The mean and standard deviation of job stress score and sleep quality were 155.42 ± 9.18 and 9.38 ± 1.62, respectively. The average eye fatigue score was 5.09 ± 0.821 in people without glasses and 4.47 ± 0.828 in people with glasses. A significant correlation was found between brightness intensity and visual fatigue ($\rho = 0.201$, $P = 0.029$). The correlation between eye fatigue and sleep quality score was also significant ($\rho = 0.225$, $P = 0.002$). However, no significant correlation was observed between lighting intensity and sleep quality ($\rho = -0.005$, $P = 0.946$). The correlation between the overall score of occupational stress and sleep quality was statistically significant ($r = -0.148$, $P = 0.042$).

Conclusions: The results showed a significant correlation between lighting intensity and the factors of sleep quality and eye fatigue. Additionally, there was a significant correlation between eye fatigue and sleep quality, as well as between occupational stress and sleep quality. Therefore, it is suggested that planning to minimize job stress, and improve lighting and sleep quality for gas refinery control room personnel should be designed and implemented by the authorities.

Keywords: Job stress-Quality, Sleep-Eye Fatigue-Gas and Oil Industry

1. Background

The increasing advancement of human societies in various fields of technology has led to a reduced physical presence of humans in the work environment, while the importance of the human factor in controlling and directing work systems has grown (1). The development of modern technologies has transformed the working environments of today's world, causing workers to face more visual and cognitive demands compared to physical ones (2, 3). The control room is an example of such a work environment, acting as the beating heart of a system, which requires optimal cognitive and visual functions.

Improper performance by control room operators can increase the probability of human error with potentially irreparable consequences (4, 5). In the control room, all processes, operations, work steps, devices, and related equipment can be controlled and monitored by operators in a centralized or decentralized manner. Therefore, a wide range of resources and facilities, including various monitors, controls, flowcharts, closed-circuit systems diagrams, audio and visual warning signs, safety devices, computers, software processors, and printers, are available in the control room (6). Many studies have shown that proper lighting positively impacts work performance and reduces incidents (7-10). Conversely, inappropriate lighting leads to increased eye fatigue, reduced performance, and a higher occurrence of incidents. Working with video display terminals in unsuitable lighting is directly related to eye disorders, affecting a person's keenness and accuracy. Numerous studies have indicated that about 75% of computer users experience vision problems (11). Fatigue can limit human attention and concentration (12). The consequences of eye fatigue include a wide range of symptoms, such as headaches, reluctance to continue working, and eye pain. The most common complaints are pain and pressure on the eyes, dry eyes, tearing, irritation and redness, blurred and double vision, and neck, back, and shoulder pain.

Another factor affecting a person's job performance during the day is their sleep quality at night. In recent years, the importance of adequate sleep for human health has been greatly appreciated. Epidemiological data show that the sufficient sleep duration for adults is 7 - 8 hours (13). Sleep disorders typically cause daytime sleepiness, affecting a person's attitude, alertness, memory, safety, and daily performance. Insufficient sleep can increase the incidence of errors while performing duties and even lead to incidents (14).

Stress is a personal experience caused by pressure or demands, affecting a person's ability to cope, or in other words, their perception of their ability (15). One of the most significant sources of stress in anyone's life is their job, and job stress has become a rampant and costly problem in work environments (16). The effects of occupational stress can be studied in three areas: Psychological, physical, and behavioral. In the psychological field, job stress is associated with job dissatisfaction, ultimately leading to depression, anxiety, sexual disorders, isolation, and aversion (17-19). The physical effects of occupational stress include cardiovascular, stomach, and intestinal diseases, sleep disorders, and headaches. Behavioral symptoms encompass individual behaviors such as taking medication, overeating or anorexia, and aggressive behaviors towards colleagues or family members. Organizational behaviors such as work absenteeism, leaving the job, and increasing incidents are also notable (20).

Sleep and rest are essential human necessities, categorized under physiological needs in Maslow's hierarchy of needs (21). Numerous factors can cause sleep disturbances and decrease sleep quality, with occupational stress being one of the main influencers. Studies have shown that increasing levels of occupational stress raise the risk of sleep disorders (22). Lack of sleep and the resulting fatigue can lead to long-term physical, mental, and health problems, such as digestive disorders, heart problems, distraction, and unsafe behaviors in the workplace. Conversely, adequate sleep can improve health, enhance performance, and reduce stress (23).

2. Objectives

The present study aimed to determine the correlation between four factors: Light intensity, eye fatigue, sleep quality, and job stress among the control room workers of Abadan Refinery. This refinery is a leading center for industrial medicine in the country and the Middle East. Attention to these global issues, especially in industrial settings like refineries, can provide valuable data on employee health to inform health and industry policymakers.

3. Methods

The present descriptive-cross-sectional study was conducted in 2022 (code of ethics: IR.BHN.REC.1401.034) to investigate the correlation between lighting intensity, eye fatigue, occupational stress, and sleep quality among the control room operators of Abadan Refinery. The sample size was calculated to be at least 185 people using the following formula:

$$Ш = \frac{1}{2}\ln\left(\frac{1+0.203}{1-0.203}\right) = 0.206$$

$$n = \frac{\left(z_{1-\frac{\alpha}{2}} + z_{1-\beta}\right)^2}{Ш^2} = \frac{(1.96+0.84)^{2}}{Ш^2}$$

$$= \frac{7.84}{0.0424} = 184.91$$

This calculation accounted for a type I error probability of 0.05 and a type II error probability of 20%, with an assumed correlation coefficient of 0.203 between sleep quality and job stress, based on the

Zamanian study (24). In this study, quantitative illuminance measurements were performed using a Hegner model lux meter at the height of the work surface during three shifts: Morning, evening, and night. General lighting intensity was evaluated based on the patterns suggested by the Illuminating Engineering Society at the work surface height of 76 cm with point lighting sources, which included a row of linear or point lights, or an arrangement of point sources in several rows (patterns A, C, and E). Recognizing the adequacy of general lighting intensity was determined by comparing the average general and local lighting with the nationally recommended limit of 300 lux. The inclusion criteria included at least one year of work experience, not holding two jobs, no history of eye surgery, no vision problems (such as cataracts, astigmatism, or uncorrected refractive errors), and no drug or alcohol consumption. The exclusion criterion was an unwillingness to continue participation at any time during the study. Non-use of drugs and alcohol was assessed based on self-reports and trust in the participants. Data were collected using an anonymous questionnaire through interviews conducted at the workplace. The study employed the Osipow Job Stress Questionnaire, the Pittsburgh Sleep Quality Index, and the Visual Fatigue Questionnaire.

The data collection questionnaire consisted of four sections: (1) demographic characteristics, (2) Osipow Job Stress Questionnaire, (3) Pittsburgh Sleep Quality Index, and (4) Visual Fatigue Assessment Questionnaire for video display terminal users.

The Osipow Job Stress Questionnaire contains 60 questions designed to examine job roles. Each of the 10 questions in this questionnaire pertains to a specific subgroup of occupational stress. The six subgroups are: (1) physical environment, (2) role ambiguity, (3) role boundary, (4) role overload, (5) role insufficiency, and (6) role responsibility.

Responses are recorded on a 5-point Likert Scale with the following numerical values: 1 = never, 2 = sometimes, 3 = often, 4 = usually, 5 = most of the time.

To measure the effect of each stress-causing subgroup, the total scores of the questions for each subgroup are calculated. To evaluate the overall stress level, the sum of scores for all 60 questions is calculated. According to the results, the effect of each tension subtype scores is categorized into four levels: Slight (10 - 19), low to medium (20 - 29), medium to severe (30 - 39), and severe (40 - 50).

Overall stress levels are also classified into four categories: Low (60 - 119), slight to moderate (120 - 179), moderate to severe (180 - 239), and severe (240 - 300) (25).

The validity and reliability of this questionnaire have been confirmed in various studies (Cronbach's alpha: 0.89) (26-28).

The Pittsburgh Sleep Quality Index is a self-report tool that evaluates sleep quality and disturbances over a 1-month period. It consists of 18 self-rated questions, which measure seven component scores, each ranging from zero to three. For interpretation purposes, zero (0) indicates no difficulty, while three (3) represents severe difficulty. The seven components are: (1) subjective sleep quality, (2) sleep latency, (3) sleep duration, (4) habitual sleep efficiency (ratio of sleep duration to elapsed time), (5) sleep disturbances, (6) use of sleep medications, (7) daytime dysfunction.

The sum of the seven component scores forms a global score, ranging from 0 to 21 points (0 = no difficulty, 21 = severe difficulties in all areas). A global score greater than 5 distinguishes poor sleepers from good sleepers, with higher scores reflecting poorer sleep patterns (29). The validity and reliability of this questionnaire have been confirmed in various studies (Cronbach's alpha: 0.83) (30-32). Eye fatigue was measured using the eye fatigue questionnaire, which includes 15 questions with a score range of 0 to 10. The alpha coefficient of this questionnaire is 0.75. The final score has a maximum of 10, categorized into areas of no fatigue (≥ 0.65), low fatigue (0.66 - 2.36), moderate fatigue (2.37 - 3.88), and severe fatigue (≤ 3.89). The questionnaire has demonstrated excellent reliability and validity, with a minimum CVI of 0.75 and a reliability coefficient of 0.755 (33).

Data analysis was performed using SPSS version 21 software. Descriptive statistics, including mean, standard deviation, frequency, and percentage indicators, were used to describe the investigated variables depending on the type of variable (quantitative or qualitative). Pearson's correlation coefficient was employed to study the correlation between quantitative variables. Multiple linear regression was also used to measure the correlation between job stress and its subgroups with sleep quality. Prior to this, the relationship between demographic and occupational stress variables and sleep quality was examined using univariate analysis, such as the independent *t*-test and one-way analysis of variance. The level of significance in the tests was considered to be 0.05.

4. Results

Table 1 provides a summary of the demographic characteristics of the studied subjects.

Table 1. Demographic Characteristics of Male Employees Working in the Control Room of Abadan Gas Refinery (N = 190)

Characteristic	Values [a]
Academic achievement	
Associate's degree	58 (30.5)
Bachelor and higher	132 (69.5)
Gender	
Man	190 (100)
Female	0
Marital status	
Single	47 (24.7)
Married	143 (75.3)
Shift work	
Yes	35 (18.4)
No	155 (81.6)
Second job	
Yes	52 (27.4)
No	138 (72.6)
Age (y)	37.87 ± 6.95 (25 - 59)
Work experience (y)	8.33 ± 5.27 (1 - 30)
Work hours per week	46.24 ± 6.94 (24 - 66)
Computer work hours	8.84 ± 1.07 (8 - 12)
Rest time during tasks (min)	52.21 ± 11.61 (30 - 70)

[a] Values are expressed as No. (%) or mean ± SD (minimum - maximum).

Table 2 displays the average, standard deviation, minimum, and maximum scores of occupational stress and its subgroups, as well as sleep quality in the studied subjects. The mean and standard deviation of the occupational stress score were 155.42 ± 9.18, and the sleep quality score was 9.38 ± 1.62, respectively.

Table 2. Mean, Standard Deviation, Minimum and Maximum Occupational Stress Score and its Subgroups, and Sleep Quality in the Control Room Operators of Abadan Gas Refinery (N = 190)

Variables	Mean ± SD	Minimum - Maximum
Job stress	155.42 ± 9.18	138 - 191
Physical work environment	11.38 ± 1.55	10 - 22
Dual role	34.35 ± 3.85	24 - 41
Role scope	28.46 ± 3.44	20 - 56
Role incompetence	32.12 ± 4.29	15 - 47
Role workload	26.94 ± 3.43	23 - 56
Role responsibility	22.25 ± 2.71	16 - 35
Sleep quality	9.38 ± 1.62	5 - 14

Pearson's correlation coefficient was used to check the correlation between occupational stress indicators and sleep quality. According to the summarized results in Table 3, there was a statistically significant correlation (P-value = 0.042) between the overall score of occupational stress and sleep quality. This correlation is inverse, with the correlation coefficient value (ρ = -0.148) indicating a weak correlation between the two variables. Among the sub-categories of occupational stress, only role workload showed a significant and inverse correlation with sleep quality (ρ = - 0.162, P-value = 0.026).

Table 3. Correlation Coefficient Between Job Stress and Sleep Quality in Abadan Gas Refinery Control Room Operators (N = 190)

Variables	Pearson Correlation Coefficients	P-Value
Job stress	- 0.148	0.042
Physical work environment	- 0.102	0.161
Dual role	- 0.089	0.221
Role scope	- 0.110	0.131
Role incompetence	- 0.009	0.905
Role workload	- 0.162	0.026
Role responsibility	0.020	0.785

The average sleep duration was 5.99 hours. The average sleep quality score was 9.38 ± 1.62, with 74.2% of participants experiencing moderate sleep problems, 25.3% experiencing serious sleep quality problems, and 0.5% having no problems. Findings revealed a significant correlation between the duration of rest time during tasks and sleep disturbance (ρ = - 0.213, P-value = 0.046). Additionally, an Independent Samples *t*-test indicated a significant association between sleep disorder and holding a second job (P = 0.41). The average sleep quality score for married individuals was 9.43 ± 1.63, and for single individuals, it was 9.23 ± 1.59, with the Independent Samples *t*-test showing no significant association between marital status and sleep quality (P-value = 0.466). This study did not find a significant correlation between work experience and sleep quality (ρ = 0.025, P-value = 0.736). The average light intensity of the work surface was determined to be 347.44 ± 139.26 lux. No significant correlation was observed between lighting intensity and sleep quality (ρ = - 0.005, P-value = 0.946). The percentage of participants with glasses in the study was 16.3%. The average eye fatigue score in people with and without glasses was 4.47 ± 0.828 and 5.09 ± 0.821, respectively. An independent samples *t*-test indicated that the difference in eye fatigue scores between people with and without glasses was significant (P-value = 0.039). Furthermore, Pearson's test showed no significant correlation between age and eye fatigue (ρ = - 0.013, P-value = 0.845). Evaluation of visual fatigue among control room operators indicated that 20% of people had low visual fatigue, while 80% showed high levels.

The results of Pearson's test exhibited a significant correlation between brightness intensity and eye fatigue (ρ = 0.201, P-value = 0.029). Additionally, Pearson's test showed a significant correlation between eye fatigue and sleep quality scores (ρ = 0.225, P-value = 0.002). However, there was no significant correlation between having a second job and eye fatigue (P-value = 0.339).

Furthermore, the research did not find any significant correlation between eye fatigue and variables such as age, work experience, average work hours, average weekly work hours, overtime, shift work, marital status, employment status, rest time during tasks, and work intensity.

5. Discussion

Poor sleep quality, whether interrupted or non-restorative, is associated with numerous negative outcomes, including health problems, reduced quality of life, and economic costs. Despite growing recognition of the consequences of sleep problems, particularly for the working population, research on the relationship between psychosocial stressors and sleep quality has been limited (34, 35). The present study examines the connection between work stressors and sleep quality using data from Abadan Refinery control room operators. The results showed an inverse and weak correlation between job stress and sleep quality. Surveys indicated a gradual deterioration of sleep quality due to increased work stress. A similar study by Deng et al. on nurses working in hospitals produced similar results (36). Moreover, among the sub-categories of occupational stress, role workload showed a significant and inverse correlation with sleep quality. Workload is a multidimensional concept involving time, task input load, operator effort, performance, and other consequences. Workload reflects the interaction of mental demands imposed on operators by the tasks they perform. Increased workload leads to elevated levels of occupational stress, which carries the risk of health problems, such as disordered sleep quality. This finding is consistent with the results of studies by Phan et al. and Litwiller et al (37, 38). The results showed that among the job stress subgroups, only "role scope" had a significant correlation with the sleep quality index score. Role scope refers to situations where the opinions and needs of employers conflict with those of employees, leading to inadequate support for the employees. According to findings from various studies, employer support in the work environment significantly reduces employees' occupational stress and depression (39).

The results indicated that 74.2% of the studied population have moderate sleep problems, 25.3% have serious sleep quality problems, and 0.5% have no problems. On the other hand, rest time during tasks and having a second job are also significant factors in sleep disorders (sleeping too much or too little). The daily rest period (DRP) is the interval between daily work consisting of sleep, leisure time, or other non-work time. According to the research of Iikeda et al., longer DRP can help regulate sleep time and reduce sleep problems such as short sleep duration, lack of sleep, social stress, and poor sleep quality (40). Wellman and his associates' research on a spectrum of working people in America showed that working a second job with long hours and non-standard schedules affects sleep duration and quality, increasing the risk of injury. In the long run, this leads to a lack of sleep, resulting in chronic insomnia (41). Regarding the influence of marital status on sleep quality, there was no significant difference in the average sleep scores between married and single individuals (42). Pearson's test also found no significant correlation between work experience and sleep quality status. However, Kim and his coworkers' study on the correlation between sleep quality and night shift rotation distance on university hospital night-shift workers concluded that individuals with more work experience were more likely to experience better sleep quality (43). Vision problems and psychological pressures such as anxiety, tiredness, lethargy, headache, eye fatigue, migraine, nausea, poor concentration, lack of mental alertness, and sleepiness during the day among employees, primarily related to insufficient light at work, frequently reduce performance and efficiency (44). Evaluations of control room operators showed that during the work period, about 20% of employees experienced low-level visual fatigue, while 80% experienced high-level visual fatigue. The current research demonstrated a significant difference between the eye fatigue scores of people with and without glasses. Zayed and his colleagues, as well as Assefa and his group, also found that computer workers who wear glasses suffer from eye strain and fatigue significantly more than those who do not wear glasses (45, 46). Pearson's test demonstrated a significant correlation between brightness intensity and eye fatigue. Low or substandard light levels cause fatigue and eye pressure, leading to headaches and eye irritation, ultimately decreasing productivity. Studies have shown that exposure to low levels of light results in reduced alertness and performance (47). A noteworthy result of the current study is the inverse and significant correlation between eye fatigue and sleep quality. This correlation reveals that the lower the amount of eye fatigue, the higher the level of sleep quality. When people are faced with insufficient light intensity in the workplace, they attempt to overcome this defect by straining their eye muscles and continuing their activities and tasks, which ultimately leads to eye fatigue and frequent headaches, known as negative factors affecting sleep quality (48). The study results revealed there is no correlation between eye fatigue and sleep quality in employees with second jobs. This finding contrasts with Rashidi et al. study on nurses working at public hospitals, which found that nurses with second jobs had better sleep quality due to being away from the stressful hospital environment, the lack of work uniformity, and the diversity in the work environment (49). One of the main reasons for the contradictory results between the present research and the mentioned literature could be the different selected groups and questionnaires used to evaluate sleep quality and disorders. Additionally, the results showed no significant correlation between eye fatigue and age, work experience, average work hours per day and week, overtime, shift work, marital status, employment status, rest time during tasks, and work severity. Tanzila Arista have reported similar results, investigating the association between light intensity, age, and work period with eye fatigue in computer users (50). Considering the role of occupational stress in decreasing sleep quality, it is essential to take measures to reduce employees' stress levels. Possible interventions include stress control training, increasing supervisors' skills in managing employees, improving welfare and motivational facilities, implementing gratitude and meditation programs, and employing experts in psychological sciences in employee care programs. Additionally, the psychological and mental burden on workers can be alleviated through codified planning, continuous revision of work schedules, and managing employees' rest time according to ergonomic guidelines.

Footnotes

Authors' Contribution: Study concept and design, N. A., and Z. H.; analysis and interpretation of data, S. T.G., and R. F.D.; drafting of the manuscript, N. A.; critical revision of the manuscript for important intellectual content, N. A., Z. H., and S. T.G.; statistical analysis, S. T.G.

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